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(54) **JAW POWERED ELECTRIC GENERATOR**

(75) Inventors: **Thomas R. Trumbull**, Los Gatos, CA (US); **Timothy P. Johnston**, Los Gatos, CA (US)

(73) Assignee: **Plantronics, Inc.**, Santa Cruz, CA (US)

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A61C 13/271	(2006.01)
A61C 5/08	(2006.01)
F03G 5/06	(2006.01)
A63B 71/08	(2006.01)

(52) **U.S. Cl.**

CPC ... ***A61C 5/08*** (2013.01); ***F03G 5/06*** (2013.01); ***H02N 2/18*** (2013.01); ***A61C 13/26*** (2013.01); *A63B 71/085* (2013.01)

(58) **Field of Classification Search**

CPC A61C 8/00; A61C 5/08; A61C 13/26; F03G 5/06; H02N 2/18; H02J 7/32

See application file for complete search history.

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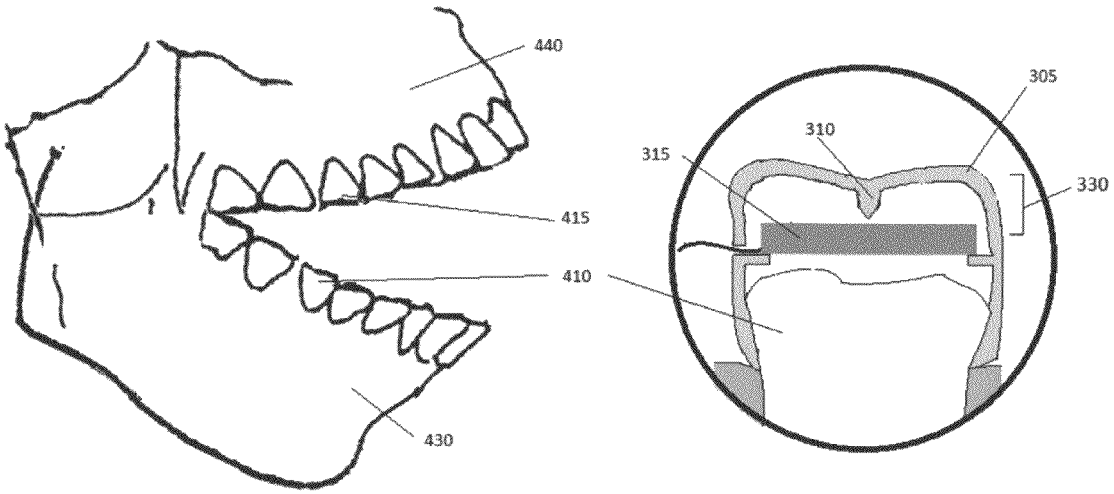
Primary Examiner — Vuthe Siek
Assistant Examiner — Aric Lin

(57) **ABSTRACT**

An electric generator powered by the opening and closing of a user's jaw. In one embodiment, a portion of an electric generator is mechanically stressed by a user's teeth when the user opens or closes his jaw. The mechanical stress is converted to electric energy and may be stored in a battery or power an electric device. In another embodiment, a magnet is passed through a coil when the user opens or closes his jaw to generate electric energy.

26 Claims, 11 Drawing Sheets



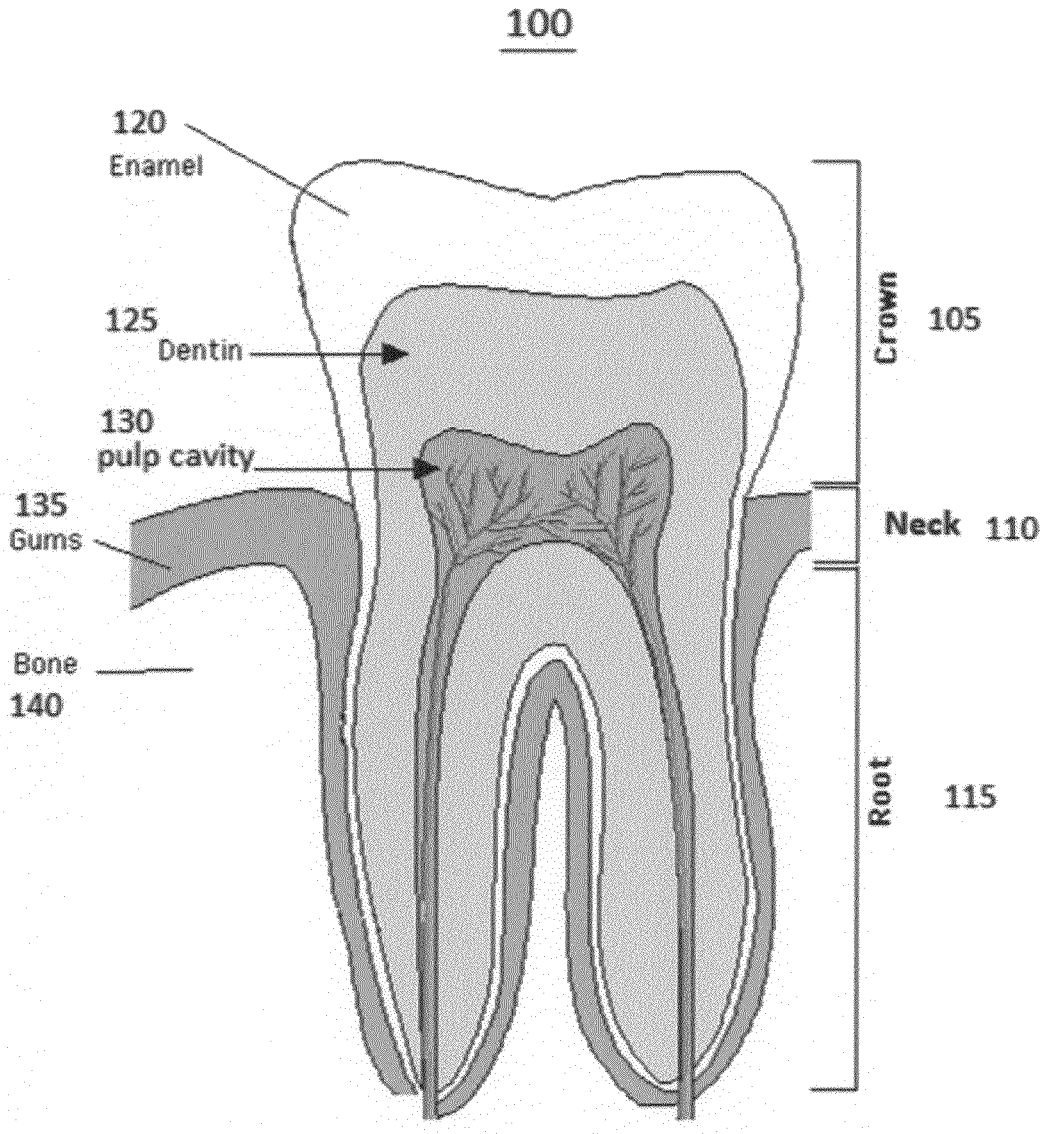


FIGURE 1

(PRIOR ART)

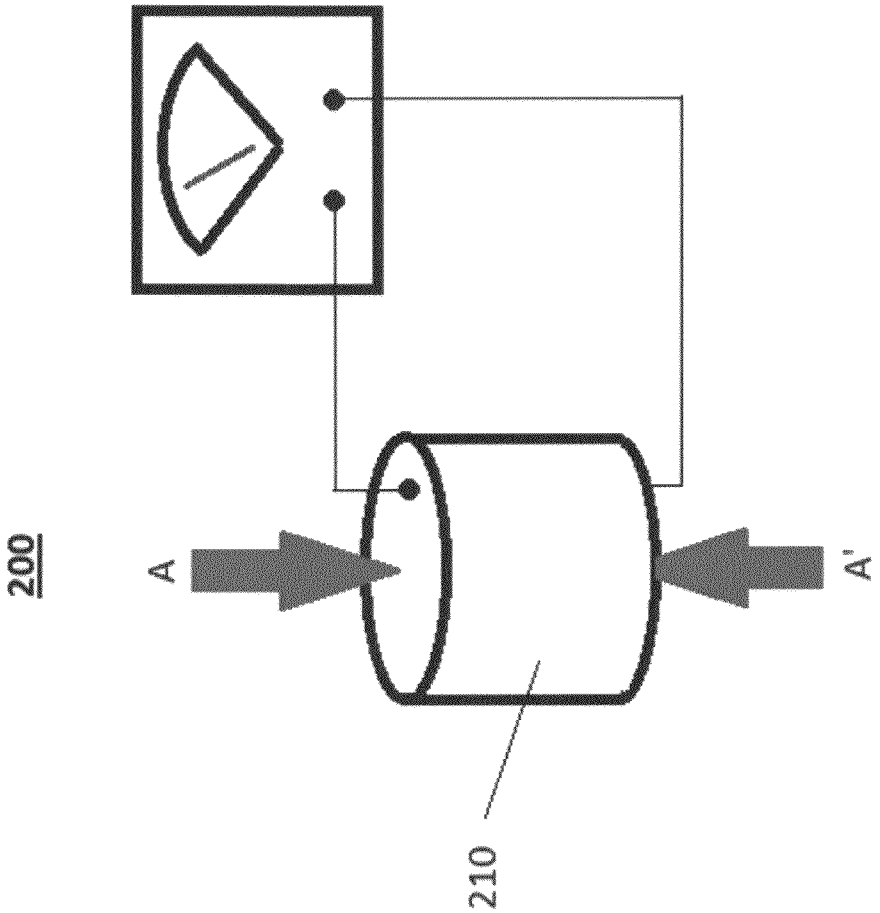


FIGURE 2
(PRIOR ART)

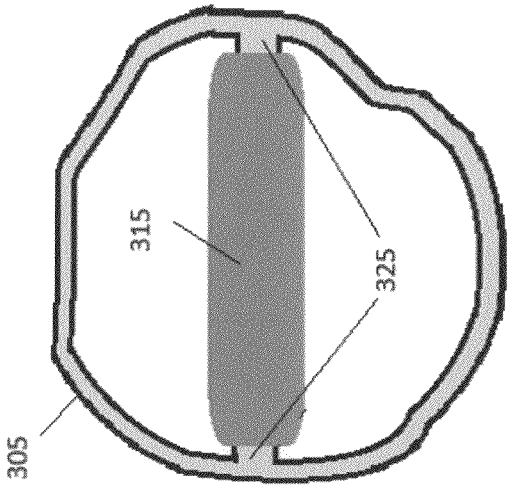


FIGURE 3B

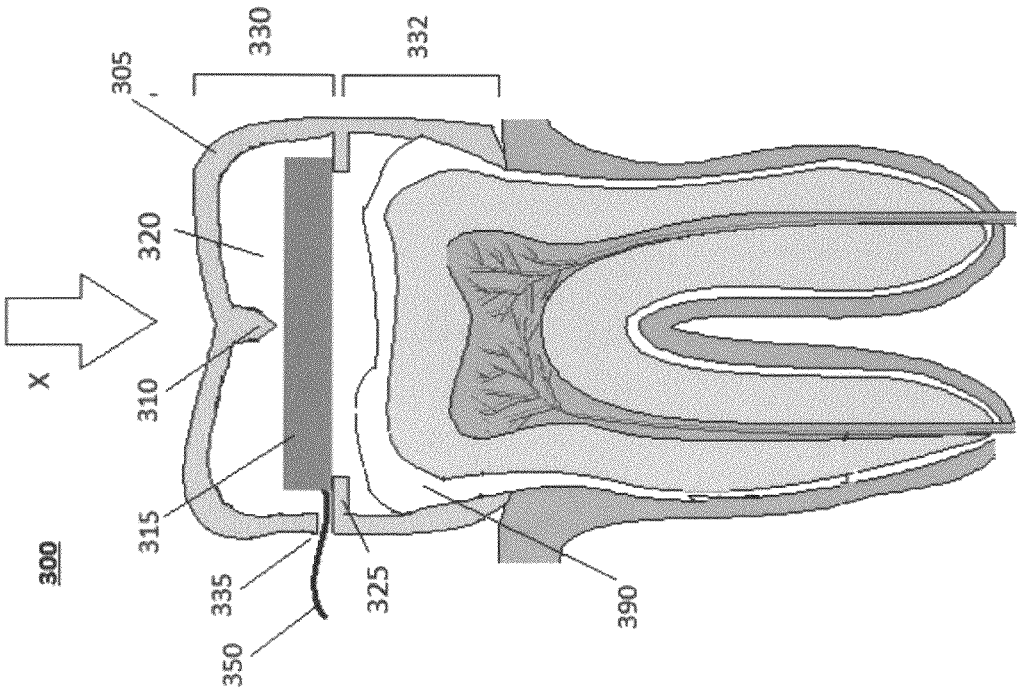


FIGURE 3A

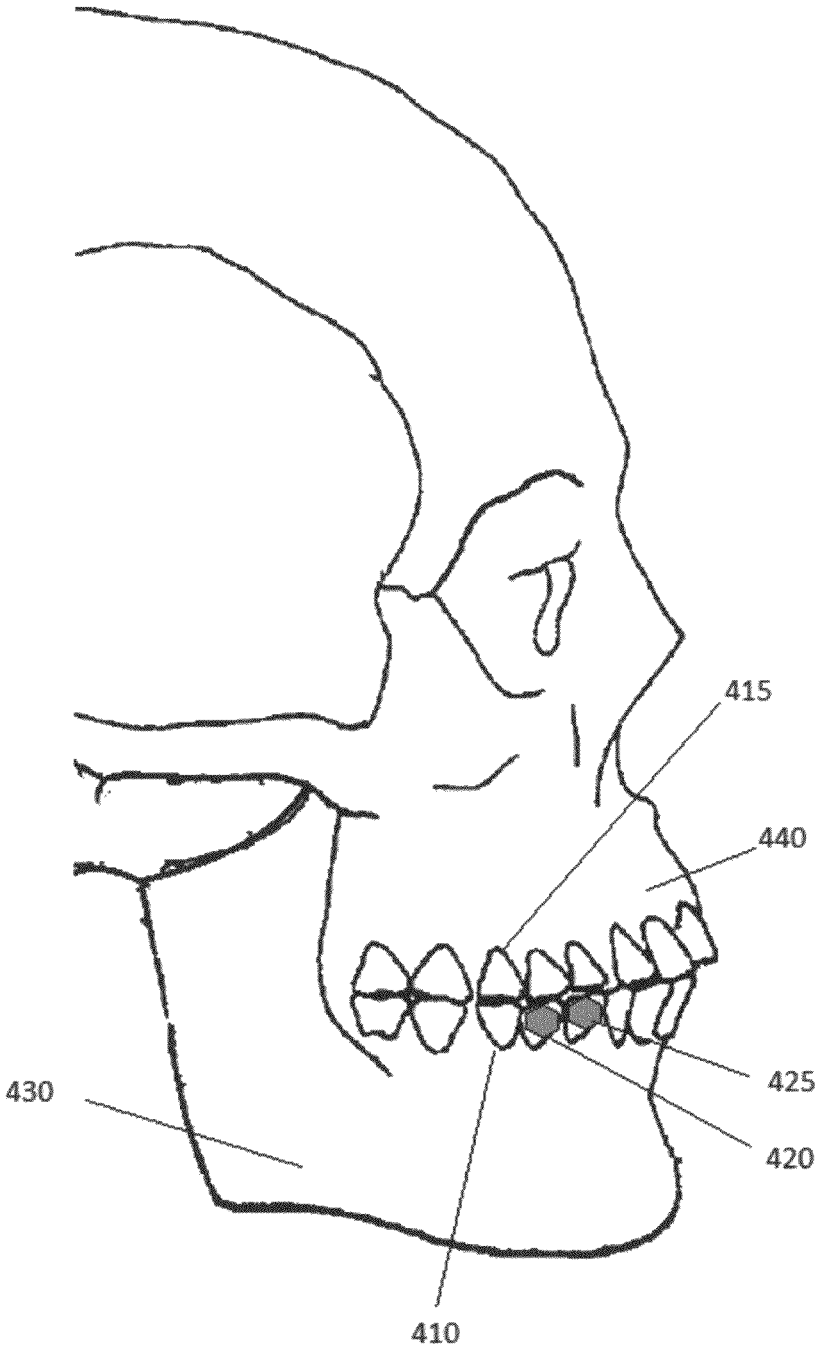


FIGURE 4

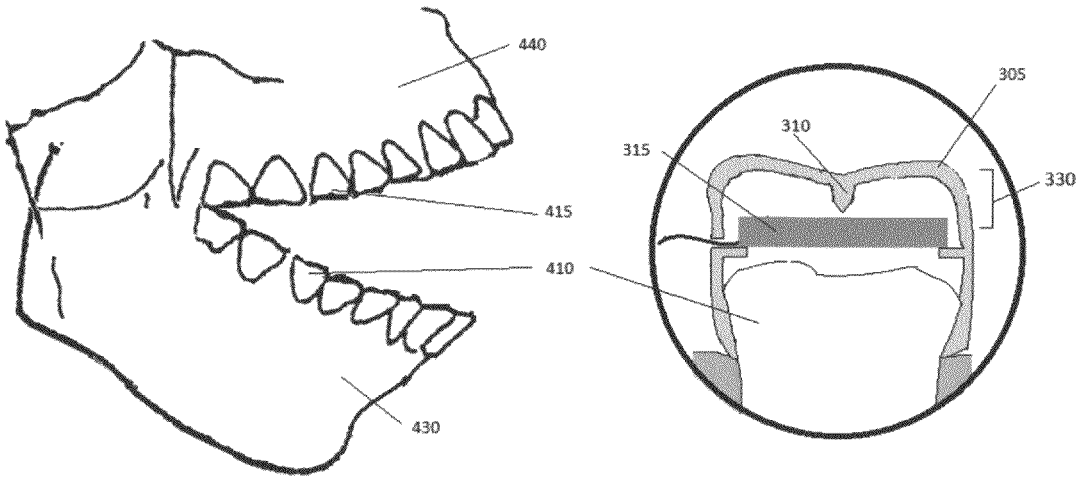


FIGURE 5A

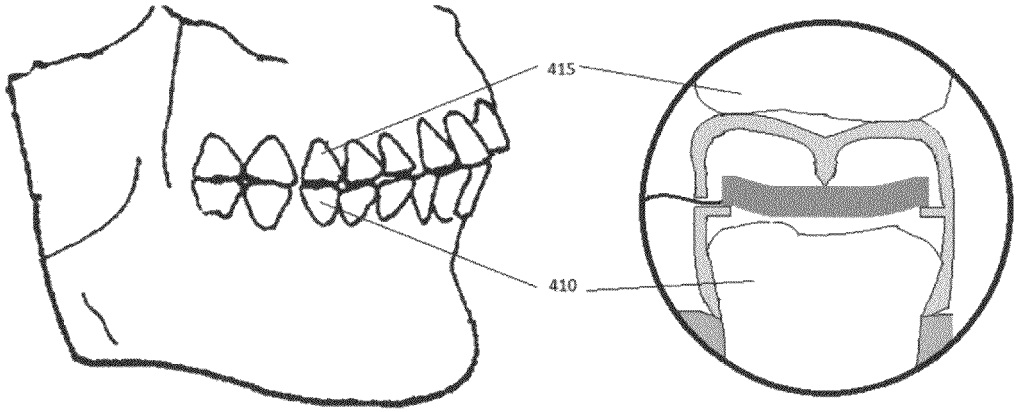


FIGURE 5B

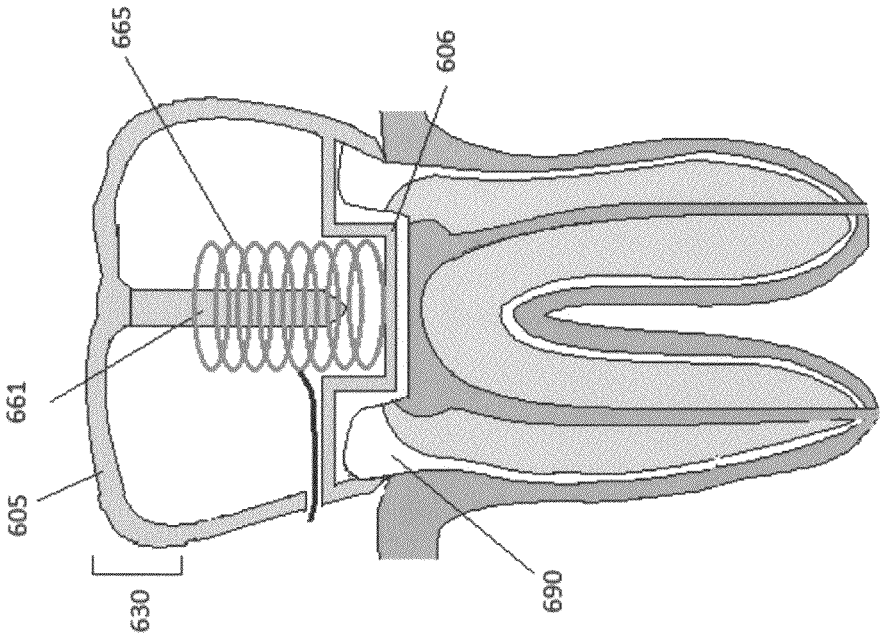


FIGURE 6B

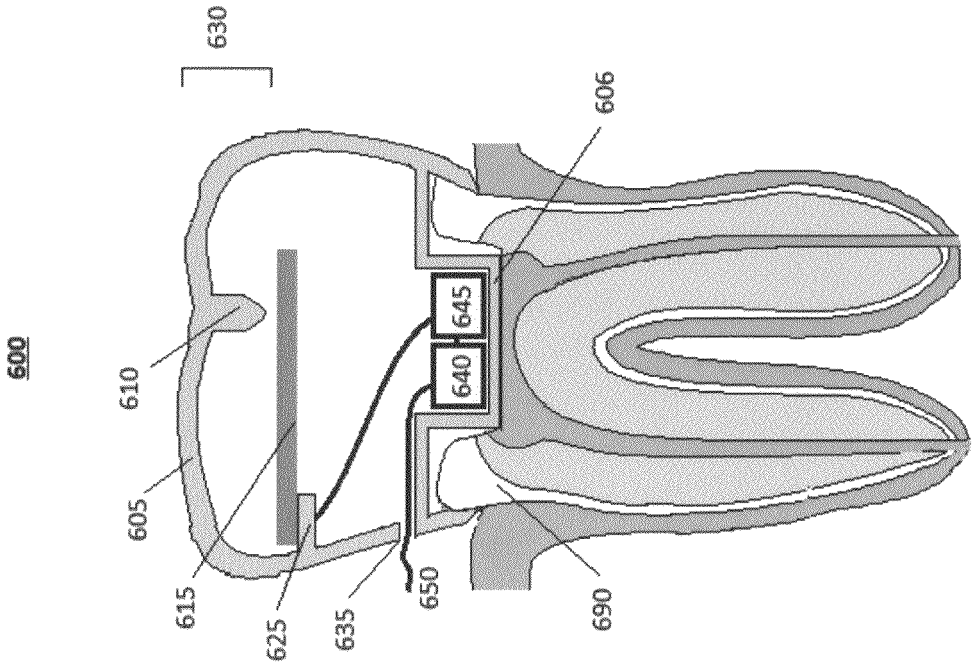


FIGURE 6A

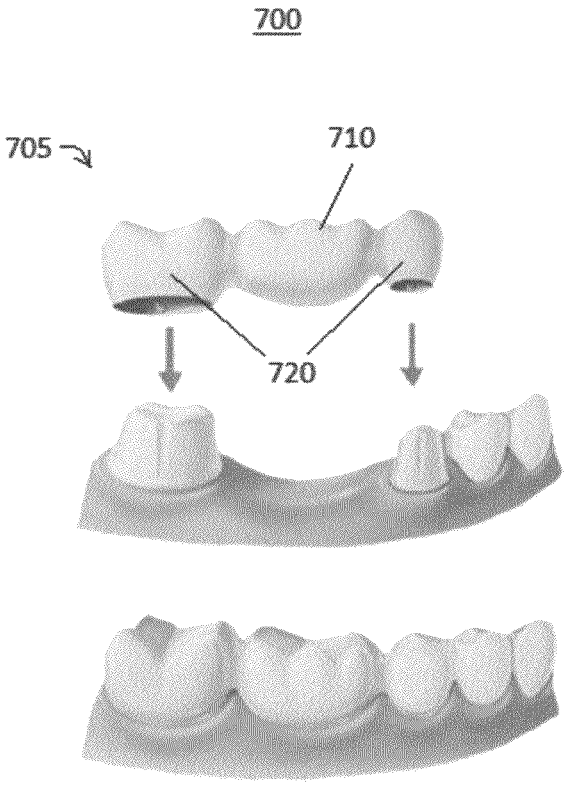


FIGURE 7

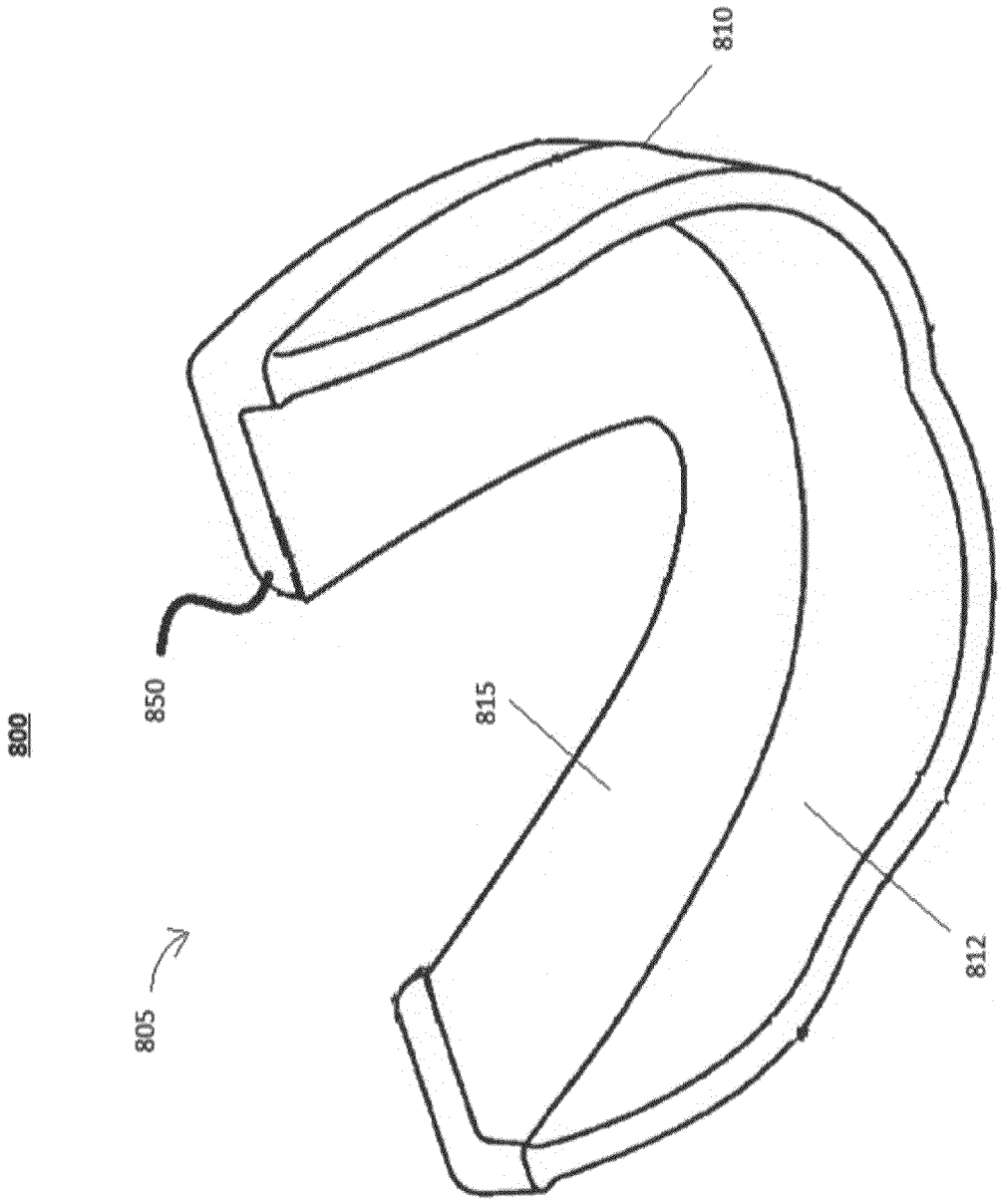


FIGURE 8A

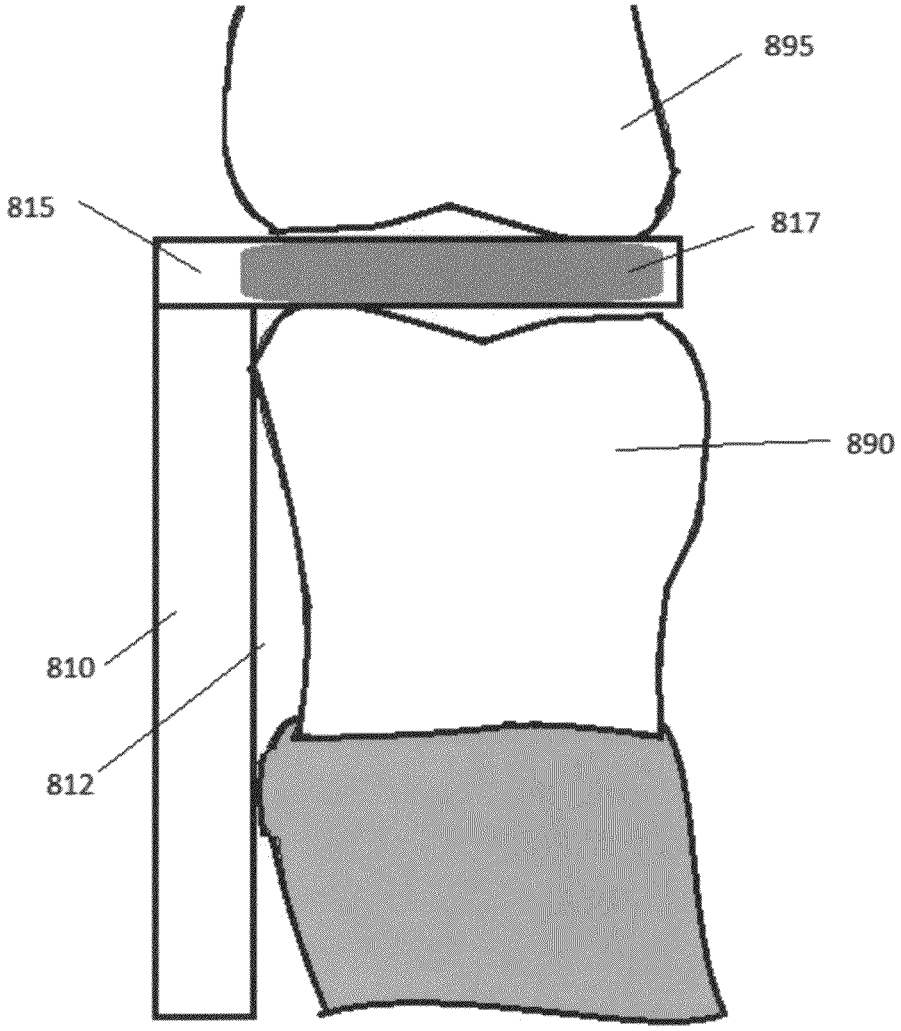


FIGURE 8B

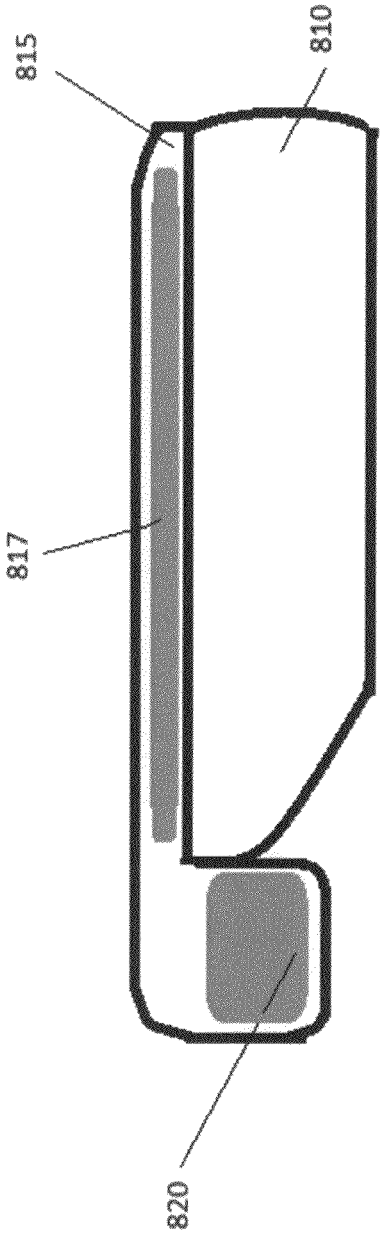


FIGURE 8C

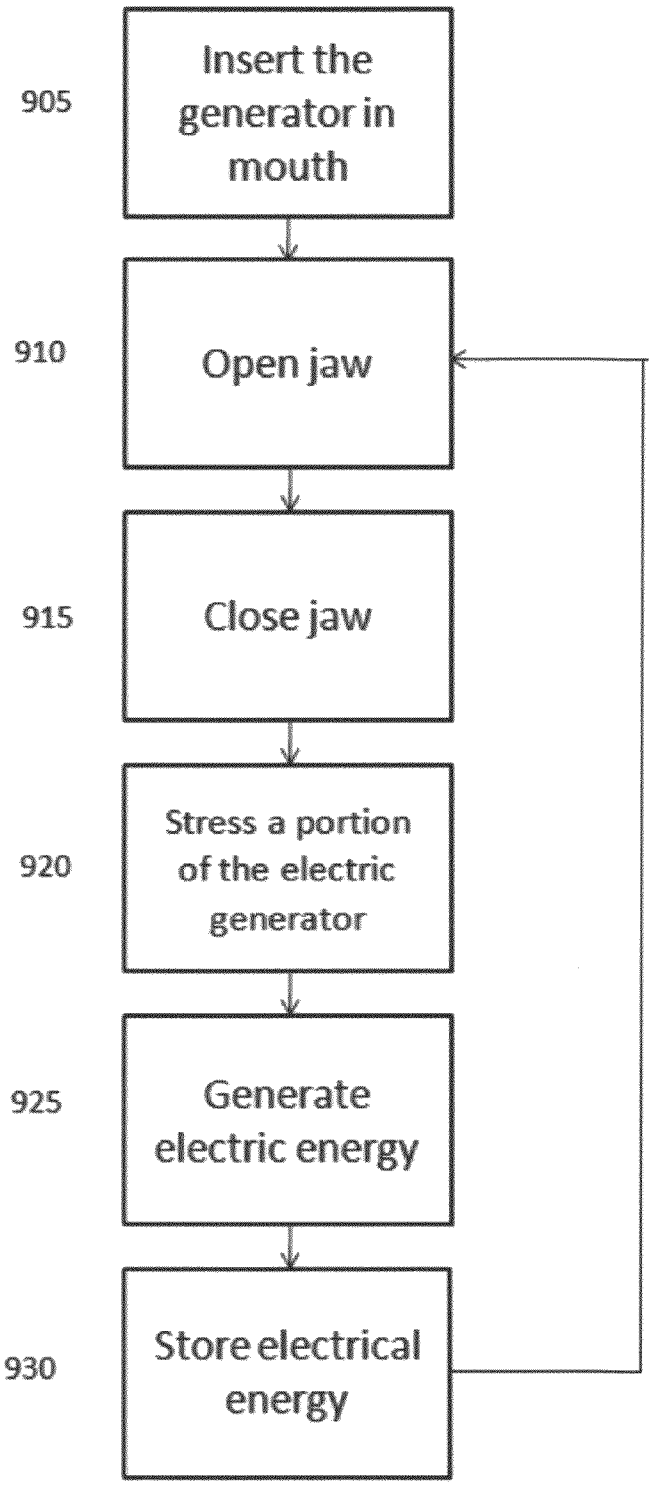

905
Insert the generator in mouth
910
Open jaw
915
Close jaw
920
Stress a portion of the electric generator
925
Generate electric energy
930
Store electrical energy

FIGURE 9

JAW POWERED ELECTRIC GENERATOR

BACKGROUND OF THE INVENTION

As electronics devices become increasingly powerful and smaller, powering these devices has become a significant concern. It may be troublesome to find compatible power sources when a user is frequently mobile and devices often require multiple recharges per day. Electronic device users typically address this issue by carrying multiple pre-charged batteries or multiple electric adapters, such as a car adapter or Universal Serial Bus adapter. This solution is cumbersome and inconvenient to the user.

SUMMARY OF THE INVENTION

According to one aspect of the invention, an apparatus comprises a first portion configured to be fixed with respect to a user's upper jaw or the user's lower jaw, a second portion configured to be movable with respect to the first portion and an electric generator adapted to generate electric energy from relative motion between the first portion and the second portion.

In one embodiment, the electric generator is located within the mouth of the user. A portion of the electric generator may be retained in a cavity defined by a portion of the first portion and a portion of the second portion. The relative motion between the first portion and second portion may be initiated responsive to relative motion between the user's upper jaw and the user's lower jaw. For example, the user may move his upper and lower jaw while talking or chewing.

The electric generator may comprise a piezoelectric transducer which may comprise a piezoelectric film and/or piezoelectric ceramic. The piezoelectric transducer is mechanically stressed by the relative motion between the first portion and the second portion. In one embodiment, the piezoelectric transducer is mechanically stressed responsive to a user's tooth applying a force to the second portion. In another embodiment, the electric generator comprises a coil and magnet. The magnetic is passed through a coil to generate electric energy responsive to a user's tooth applying a force to the second portion.

The apparatus may further comprise a circuit, such as a rectifier, for converting the electric energy to direct current. A battery may be configured to store the electric energy. The battery may be removably coupled to the user, such as coupling the battery to a user's tooth. After the battery is charged, the battery may be decoupled from the user's tooth and placed in an electronic device. Alternatively, the apparatus may provide electric energy directly to an electronic device.

The apparatus may be implemented in an artificial tooth or fake tooth such as a pontic. In this embodiment, the artificial tooth may comprise a first portion configured to be fixed with respect to a user's upper jaw or the user's lower jaw, a second portion configured to be movable with respect to the first portion and an electric generator adapted to generate electric energy from relative motion between the first portion and the second portion.

In another embodiment an apparatus comprises a cap coupled to a portion of a tooth and an electric generator adapted to generate electric energy from relative motion between the cap and the portion of the tooth. The tooth may be physically coupled to a user's upper jaw or the user's lower jaw, and the relative motion between the cap and the portion of the tooth may be initiated responsive to relative motion between the user's upper jaw and the user's lower jaw.

The electric generator may comprise a piezoelectric transducer having a piezoelectric electric film and/or piezoelectric ceramic. The piezoelectric transducer may be mechanically stressed by the relative motion between the cap and the portion of the tooth. The mechanical stress may be responsive to a user's tooth applying a force to the cap. Alternatively the electronic generator may comprise a coil and magnet. A portion of the electric generator may be retained in a cavity defined by the portion of the tooth and the cap.

The apparatus may further comprise a circuit, such as a rectifier, for converting the electric energy to direct current. A battery may be coupled to the circuit to receive and store electric energy. The battery and/or circuit may be removably coupled to the user. The battery and/or circuit may be stored within a cavity defined by the cap and portion of the tooth or stored elsewhere in the user's mouth such as on the surface of adjacent teeth. After the battery is charged, the battery may be decoupled from the user and placed in an electronic device. Alternatively, the apparatus may provide electric energy directly to an electronic device.

Another embodiment of the present invention comprises a method for generating electric energy wherein generating the electric energy comprises mechanically stressing a portion of an electric generator. Mechanically stressing the portion of the electric generator comprises at least one of opening a human jaw, and closing the human jaw. The method may further comprise storing the electric energy in a battery.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a diagram of the anatomy of a tooth;

FIG. **2** illustrates a conventional piezoelectric generator;

FIG. **3**A is a cross-sectional side view of a jaw generator on a tooth;

FIG. **3**B is a cross-sectional top view of a jaw generator on a tooth;

FIG. **4** is a cross-section side view of the jaw generator of FIG. **3** placed in a user's mouth;

FIG. **5**A and FIG. **5**B is an illustration of the jaw generator of FIG. **3** in use;

FIG. **6**A is a drawing of the jaw generator in accordance with another embodiment of the present invention;

FIG. **6**B is a drawing of the jaw generator in accordance with another embodiment of the present invention;

FIG. **7** is a drawing of the jaw generator in accordance with another embodiment of the present invention;

FIG. **8**A is a drawing of the jaw generator in accordance with another embodiment of the present invention;

FIG. **8**B is a cross sectional view of the jaw generator of FIG. **8**A placed in a user's mouth.

FIG. **8**C is a drawing of the jaw generator in accordance with another embodiment of the present invention;

FIG. **9** is a flow chart diagram of the jaw generator in operation.

DETAILED DESCRIPTION OF THE DRAWINGS

The following description is presented to enable any person skilled in the art to make and use the invention. Descriptions of specific embodiments and applications are provided only as examples and various modifications will be readily apparent to those skilled in the art. The general principles defined herein may be applied to other embodiments and applications without departing from the spirit and scope of the invention. Thus, the present invention is to be accorded the widest scope encompassing numerous alternatives, modifications and equivalents consistent with the principles and fea-

tures disclosed herein. For purpose of clarity, details relating to technical material that is known in the technical fields related to the invention have not been described in detail so as not to unnecessarily obscure the present invention.

Furthermore, those skilled in the art will appreciate that the reference to a tooth as used herein is intended to encompass any type of tooth, including but not limited to molars, premolars, third molars, wisdom teeth, incisors, canines and artificial teeth such as dental bridges and dental crowns.

Referring to FIG. **1**, shown is a diagram of a molar tooth **100**. The tooth **100** comprises a crown **105**, neck **110**, root **115**, enamel **120**, dentin **125**, and pulp cavity **130**. The base of the tooth **100** is surrounded by gums **135** and a portion of the jaw bone **140**.

Conventionally, the crown **105** is considered the visible portion of the tooth above the neck **110**. The crown **105** is generally completely covered by enamel **120**. Below the layer of enamel **120** is a layer of dentin **125**. Below layer of dentin **125** is the pulp cavity **130**. The pulp cavity **130** may contain blood vessels and nerves that run through the pulp of the tooth. The root **115** is conventionally considered the portion of the tooth below the neck **110**. The root **115** assists in anchoring the tooth **100** into the jaw bone **140**.

Referring to FIG. **2**, shown is an illustration of an electric generator in the form of a conventional piezoelectric transducer **200**. The piezoelectric transducer **200** comprises a piezoelectric element **210**. The piezoelectric element **210** converts electric energy into mechanical vibrations (transmit mode) and mechanical vibrations into electric energy (receive mode). The piezoelectric element **210** may comprise materials known in the art including but not limited to ceramics, crystals, and magnetostrictive materials. In receive mode, the piezoelectric element **210** generates electric energy when deformed (i.e. in response to applied mechanical stress or force). In one embodiment, the piezoelectric element **210** generates electric energy when a force at AA' is applied and mechanical stress occurs.

Referring to FIG. **3** shown is a cap **305**, piezoelectric element **315** and a tooth **390** according to one embodiment **300**. The cap **305** comprises at least one top protrusion **310**, a top portion **330**, a base portion **332**, an aperture **335** and support protrusions **325**.

The cap **305** is coupled to the tooth **390**. Similar to a dental crown, the cap **305** may be shaped to the dimensions of a tooth's crown and configured to cover the tooth **390**. When coupled, the cap **305** can fully encase the visible portion of the tooth **390** that lies at and above the gum line, but this is not required. The cap **305** comprises an open end at the base portion **332** for receiving the tooth **390**. The cap **305** may be removably coupled to the tooth **390**. Alternatively, the cap **305** may be permanently coupled to the tooth **390** by an adhesive such as glue or cement.

The cap **305** may be made from one or more materials suitable for dentistry such as ceramics, resins, porcelain, alloys and metals. When coupled, the tooth **390** and cap **305** define a cavity **320** wherein the piezoelectric element **315** is disposed. The piezoelectric element **315** may be a piezoelectric ceramic or piezoelectric film and may take various forms such as a strip, disk or block. Electric wires **350** connect the piezoelectric element **315** to a circuit or energy storage device (not shown) by passing through the aperture **335** in cap **305**.

The top portion **330** of the cap **305** is configured to deform toward the piezoelectric element **315** when a force X is applied to the upper surface of the cap **305** and uncompress to its original shape when a force is no longer applied. The elasticity of the top portion **330** may be achieved by choice of material, thickness and/or form design. The top portion **330** may be made from a different material than the base portion **332**. The base portion **332** is fixed with respect to the tooth **390** and user's jaw; it is configured to keep the cap **305** rigidly coupled to the tooth while the top portion **330** is compressed.

The top protrusion **310** extends from the inner surface of the top portion **330** toward the piezoelectric element **315** and is configured to apply a force to the piezoelectric element **315** when force X is applied. When the top portion **330** is uncompressed, the top protrusion **310** is sufficiently positioned to not apply a force to the piezoelectric element **315**.

The piezoelectric element **315** is coupled to one or more support protrusions **325**. The support protrusions **325** are configured to support the piezoelectric element **315** in the cavity **320** and provide lateral support. The support protrusions **325** may be made from the same material and/or mold as the cap **305**. Referring to FIG. **3**A and FIG. **3**B, support protrusions **325** extend a finite length from the inner surface of the cap **305** to support the outer edge of the piezoelectric element **315**. It should now be understood that the piezoelectric element **315** is suspended in cavity **320** and can be mechanically stressed by the top protrusion **310** when the top portion **330** is compressed. In an alternative embodiment, support protrusions **325** may comprise one piece to support the entire body of the piezoelectric element **315**.

The operation of the embodiment **300** can now be understood. Turning to FIG. **4**, shown is the cap **305** of FIG. **3** placed in the mouth of a user on tooth **410** at the lower jaw **430**. When selecting a tooth to couple the cap **305** onto, it is preferred to select a tooth that has a corresponding tooth on the opposing jaw such that the opposing tooth applies adequate force to the cap **305** when the user's jaw is closed. In some cases, one or more corresponding teeth on the opposite jaw may apply force to the selected tooth when the user's jaw is closed. Tooth **410** has a corresponding tooth **415** located on the upper jaw **440**.

Referring to FIG. **5**A, shown is the cap **305** and tooth **410** when the user's jaw is in an open position. In the open position, no force or insufficient force is applied to the cap **305** and the piezoelectric element **315** is not mechanically stressed. When the user's jaw transitions to a closed position as seen in FIG. **5**B, the tooth **415** applies a force to the cap **305** at the top portion **330**. The top portion **330** is compressed toward the piezoelectric element **315** and the top extension **310** applies a force to the piezoelectric element **315**. The force applied to the piezoelectric element **315** causes mechanical stress (e.g. deformity), and in turn the piezoelectric element **315** produces electric energy. When the user's jaw transitions to back to an open position (FIG. **5**A), the top portion **330** returns to an uncompressed state and the top protrusion **310** no longer applies a force to the piezoelectric element **315**. In turn the piezoelectric element **315** also returns to an unstressed state and produces electric energy. When the user's jaw repetitively transitions to and from an open and closed position, the piezoelectric element **315** generates electric energy in the form of alternating electric current.

The alternating current may be transported by electric wires **350** to an electric circuit **420** such as a rectifier to convert the alternative current to direct current. The electric circuit **420** may be electrically coupled to an energy storage device **425** (shown in FIG. **4**) such as a battery or capacitor, for storing the direct current. The electric circuit **420** and energy storage device **425** may be located on the surface of adjacent teeth. In one embodiment they are electrically coupled by wires. Alternatively, they may be electrically coupled by conductive contacts placed between adjacent teeth.

Referring to FIG. **6**A, shown is an alternative embodiment **600** in which the piezoelectric element **615** takes the form of a cantilever. In this embodiment, the piezoelectric element **615** is anchored by a support protrusion **625** at one end; the top protrusion **610** may be disposed near the opposite end of the piezoelectric element **615**. Furthermore, the top protrusion **610** extends from the inner surface of the top portion **630** toward the piezoelectric element **615**. If the user has had a root canal procedure, a portion of the root of the tooth **690** is removed and the pulp cavity within the center of the tooth can be made available to house an electric circuit **640** and energy storage device **645**. The electric circuit **640** and energy storage device **645** may be coupled directly to the inner surface of the pulp cavity or be supported by a substrate **606**. Electric wires **650** connect the electric generator directly to an electronic device (not shown) by passing through an aperture **635** in cap **605**.

Referring to FIG. **6**B, shown is an alternative embodiment **660** in which the electric generator takes the form of a magnet **661** and coil **665**. The magnet **660** is coupled to the inner surface of the top portion and extends downward. The coil **665** may be fixed to a substrate **606**. In this embodiment, a magnet **660** is passed through the center of the coil **665** when a sufficient force is applied to the top portion **630** of the cap **605**. The movement of the magnet **661** through the coil **665** induces an electric current as the user opens and closes his jaw. Alternatively, the position of the magnet **661** and coil **665** may be reversed such that the magnet **661** is fixed to the substrate **606** and the coil **665** is coupled to the inner surface of the top portion **630**.

Referring to FIG. **7**, shown is an alternative embodiment **700** wherein the jaw-powered electric generator takes the form of dental bridge **705**. The dental bridge **705** comprises a pontic **710** and crowns **720**. In this embodiment, an electric generator similar to those of embodiments **300** and **600** is implemented in the pontic **710**. An array of electric generators may be arranged if the crowns **720** also include electric generators similar to those of embodiments **300** or **600**.

Referring to FIG. **8**A, shown is another embodiment diagram wherein the jaw-powered electric generator takes the form of a retainer **805**. The retainer **805** comprises a base **810** and a lip portion **815**. The retainer **805** is shaped to conform to the lower portion of the user's mouth much like a traditional mouth guard or dental retainer. It will be appreciated that the retainer **805** may alternatively be configured to conform to the upper portion of the user's mouth (e.g., upper jaw).

The base **810** is U-shaped and surrounds the user's lower teeth when the retainer **805** is placed in the user's mouth. The base **810** has an inner surface **812** which comes into contact with a portion of the user's teeth and a portion of the lower gums. The base **810** may comprise materials known in the art including but not limited to polymers, plastics and silicone. The lip portion **815** extends from one end of the base portion **810** toward the center of the mouth such that a portion of the lip portion **815** covers the top surface of the user's teeth. A portion of the lip portion **815** is a made from a compressible piezoelectric material **817** (shown in FIG. **8**C). The piezoelectric material **817** of the lip portion **815** may be encased in the same material as base **810**. An electric wire **850** connects the lip portion **815** to a circuit or energy storage device (not shown).

FIG. **8**B shows a cross-sectional view of a portion of the retainer **805** when placed in the user's mouth. The operation of the device can now be understood. Similar to the embodiments **300**, **600**, **660** and **700** the lip portion **815** is not mechanically stressed when the jaw is in an open or rest position. In the rest position, no force or insufficient force is applied to the lip portion **815**. When the user's jaw transitions to a closed position the tooth **890** and opposing tooth **895** compresses/stresses the lip portion **815** and consequently compresses/stresses piezoelectric material **817**. This phenomenon occurs across the entire array of teeth. When the user repetitively transitions to and from an open and closed position, the piezoelectric material **817** generates electric energy in the form of alternating current.

The base **810** and lip portion **815** may cover all or some of the user's teeth. The base **810** may be configured to be lingual, buccal, distal or a combination thereof. Furthermore, the portions of the lip portion **815** may have various thicknesses and dimensions to account for the various types of teeth surfaces.

FIG. **8**C shows an alternative embodiment wherein an end portion **820** may extend toward the back of the mouth. The end portion **820** may extend from lip portion **815** such that a portion of the end portion **820** covers a portion of the user's gum, such as an operculum. The end portion **820** comprises a compressible piezoelectric material such as a piezoelectric ceramic. When the user's jaw transitions to an open and closed position the end portion **820** is stressed and unstressed by the user's gums to generate electric energy.

FIG. **9** shows a flow chart demonstrating the jaw powered generator in use. At step **905**, generator is placed in the user's mouth. The generator rests in the user's mouth until the user opens his jaw at **910**. Next, the user closes his jaw **915**. Opening **910** and closing **915** may be invoked by typical actions of the mouth such as talking, chewing, and biting. One benefit of the invention is the user generates power throughout the day using the natural use of his mouth without conscious effort. The user may also purposely invoke steps **910** and **915** with the intent to generate electric energy. Also the sequence of steps of opening **910** and closing **915** the jaw may be reverse although not explicitly shown in FIG. **9**. At step **920** a portion of the electric generator is mechanically stressed or deformed. In the case of the embodiments of **300** and **600** a portion of a cap is compressed to deform a piezoelectric element **315**. In the case of embodiment **660** a portion of a cap is compressed to move a magnet through a coil. In the case of embodiment **660** a portion of a cap is compressed to move a magnet **661** through a coil **665**. In the case of embodiment **800** opposing teeth compress a lip portion **815**. At step **930** the electric energy is storage in an energy storage device such as a battery **645**. The electric energy may be sent to an appropriate electric circuit **640** such as a rectifier prior to the storage device to convert the electric energy to direct current. Next, the method returns to step **910** and repeats when the user open and closes his jaw.

What is claimed is:

1. An apparatus comprising:

a first portion configured to be fixed with respect to a user's upper jaw or the user's lower jaw;

a second portion configured to be movable with respect to the first portion; and

an electric generator adapted to generate electric energy from relative motion between the first portion and the second portion, wherein the electric generator comprises a piezoelectric transducer.

2. The apparatus of claim **1**, wherein the relative motion between the first portion and second portion is initiated responsive to relative motion between the user's upper jaw and the user's lower jaw.

3. The apparatus of claim **1**, wherein the piezoelectric transducer is mechanically stressed by the relative motion between the first portion and the second portion.

4. The apparatus of claim 1, wherein the piezoelectric transducer is mechanically stressed responsive to a user's tooth applying a force to the second portion.

5. The apparatus of claim 1, wherein the piezoelectric transducer comprises a piezoelectric film.

6. The apparatus of claim 1, wherein the piezoelectric transducer comprises a piezoelectric ceramic.

7. The apparatus of claim 1, further comprising a circuit for converting the electric energy to direct current.

8. The apparatus of claim 1, further comprising a battery configured to store the electric energy.

9. The apparatus of claim 8, wherein the battery is removably coupled to the user.

10. The apparatus of claim 1, wherein the electric generator is located within the mouth of the user.

11. An artificial tooth comprising the apparatus of claim 1.

12. An apparatus comprising:

a first portion configured to be fixed with respect to a user's upper jaw or the user's lower jaw;

a second portion configured to be movable with respect to the first portion; and

an electric generator adapted to generate electric energy from relative motion between the first portion and the second portion, wherein at least a portion of the electric generator is retained in a cavity defined by a portion of the first portion and a portion of the second portion.

13. An apparatus comprising: a cap coupled to a portion of a tooth; and an electric generator adapted to generate electric energy from relative motion between the cap and the portion of the tooth.

14. The apparatus of claim 13, wherein the electric generator comprises a piezoelectric transducer.

15. The apparatus of claim 14, wherein the piezoelectric transducer is mechanically stressed by the relative motion between the cap and the portion of the tooth.

16. The apparatus of claim 14, wherein the piezoelectric transducer is mechanically stressed responsive to a user's tooth applying a force to the cap.

17. The apparatus of claim 14, wherein the piezoelectric transducer comprises a piezoelectric film.

18. The apparatus of claim 14, wherein the piezoelectric transducer comprises a piezoelectric ceramic.

19. The apparatus of claim 13, wherein the electric generator comprises a coil and magnet.

20. The apparatus of claim 13, wherein the tooth is physically coupled to a user's upper jaw or the user's lower jaw, and wherein the relative motion between the cap and the portion of the tooth is initiated responsive to relative motion between the user's upper jaw and the user's lower jaw.

21. The apparatus of claim 13, further comprising a circuit for converting the electric energy to direct current.

22. The apparatus of claim 13, further comprising a battery configured to store the electric energy.

23. The apparatus of claim 13, wherein the battery is removably coupled to the user.

24. The apparatus of claim 13, wherein at least a portion of the electric generator is retained in a cavity defined by the portion of the tooth and the cap.

25. A method comprising:

generating electric energy; wherein generating the electric energy comprises mechanically stressing a portion of an electric generator;

wherein mechanically stressing the portion of the electric generator comprises at least one of opening a human jaw, and closing the human jaw.

26. The method of claim 25, further comprising storing the electric energy in a battery.

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